Analysis of Market Strategies of Farmers in the Upper West Region of Ghana : A Spatial Equilibrium Approach

著者	Ndamani Francis
journal or publication title	Journal of Developments in Sustainable Agriculture
volume	3
number	2
page range	104-116
year	2008
URL	http://hdl.handle.net/2241/113018

Journal of Developments in Sustainable Agriculture 3: 104–116 (2008)

Analysis of Market Strategies of Farmers in the Upper West Region of Ghana: A Spatial Equilibrium Approach

Francis Ndamani

Graduate School of Life and Environmental Sciences, University of Tsukuba,
Tsukuba, Ibaraki 305-8572, Japan

Agriculture remains the bedrock of the Ghanaian economy. Apart from employing about 60% of the total workforce of the country, the sector contributes 30% to GDP. However, agricultural production is largely undertaken by smallholder subsistence farmers who rely solely on highly unpredictable and sporadic seasonal rainfall. Maize, sorghum, and groundnut are the main crops cultivated by most farmers, particularly in northern Ghana. These crops are the principal sources of food and income for farm households. Therefore, variability in prices of the crops at different markets tends to adversely affect the incomes and food security of poor rural farmers. Avoiding such adverse effects, however, requires informed decision making by producers based on good understanding of the trends of supply and demand. Hence, in this study, I applied a spatial equilibrium model in the Upper West Region of Ghana to identify market strategies that influence the marketing and production decisions of farmers and the technology dissemination decisions of agricultural staff. The data used in the study include wholesale and retail crop prices (2002–2007), production/yield figures, and commodity transport costs sourced from District Agricultural Development Units for three markets in the region. Data on the Consumer Price Index was obtained from the Ministry of Finance and Economic Planning of Ghana. In general, the annual average price of maize and sorghum are higher in Wa market than in Tumu or Lawra markets. Comparison of linear and quadratic programming results showed that farmers attain different produce prices (incomes) depending on whether they are price makers or price takers. Farmers in this region are generally risk averse, so they like to ship their produce to different markets. Considering these findings, it is advisable for farmers to form organizations or groups to market their products collectively. In addition, established groups should network to facilitate the exchange of market information.

Key words: Market Strategies, Spatial Equilibrium, Farmers' Group, Upper West Region, Ghana

1. Introduction

Agriculture remains the bedrock of the Ghanaian economy. Apart from employing about 60% of the total workforce of the country, the sector contributes 30% to GDP. However, agricultural production is largely undertaken by smallholder subsistence farmers who rely solely on seasonal rainfall, which is highly unpredictable and sporadic. Maize, sorghum, and groundnut are the main crops cultivated by most of these farmers, particularly in northern Ghana. These crops constitute the principal sources of food and income for farm households.

Despite many interventions (e.g., Ghana P Poverty Reduction Strategy, Food and Agricultural Sector Development Program and international donor projects) to increase agricultural productivity, the country has yet to achieve food and income security. The quantities of crops produced in Ghana are inadequate to meet the food needs of the people. Therefore, the country consistently relies on food imports from Burkina Faso, Thailand, the United States, and several other countries. According to the Ghana Statistical Service (GSS), in 2004, for instance, Ghana imported 140 Mt of maize,

Received: October 2, 2008, Accepted: November 13, 2008
Corresponding author's current address: Ministry of Food and Agriculture, P.O. Box 21, Upper West Region, Ghana.
Tel: +233 242 04 52 68, Fax: +233 756 22261, E-mail: pudolar@yahoo.com

253,905 Mt of rice and 2.6 Mt of sorghum (Ministry of Food and Agriculture, 2006). Against the backdrop of an increasing population and urbanization in Ghana, persistent supply shortages can be predicted in the face of soaring demand. The perennial food crop deficit can, however, be attributed to poor planning and local market failure.

Most rural development efforts in Central and West Africa have focused on how to improve poor farmers' yields. However, better yields do not necessarily translate into greater incomes as expected. Studies have revealed that in Ghana, Nigeria, and Ethiopia, for example, a boost in crop production culminated in a glut on the market and depressed prices (International Fund for Agricultural Development 2007; Getnet, 2007). Moreover, marketing uncertainty, faced especially by smallholders, dampens production incentives and contributes to stagnation in agricultural output and productivity (Coulter and Onumah, 2002). Food crop markets are therefore fundamentally relevant to the problem of attaining income and food security. A good knowledge of food crop market strategies would help farmers minimize market shocks and avoid getting low prices for their produce.

As rain-fed crops, maize, sorghum, and groundnut are generally cultivated and harvested between June and December. Owing to their seasonal nature, prices of these crops generally tend to decrease during the harvest and immediate post-harvest period and surge during the rest of the year. These crops are traded between the producers and many other market actors, including wholesalers, retailers, consumers, and local assemblers. Because of the importance of these crops to smallholder farmers (both as staple and cash crops), it is desirable to investigate the marketing strategies that are most appropriate for avoiding low product prices.

It is well known that price variability of food crops at different market locations tends to adversely affect income and food security of poor rural farmers and poor urban consumers. Therefore, analysis of the supply and demand trends of food crops in various markets is essential for informed decision making by both producers and consumers. In this study, using six (6) years of food crop prices and shipment quantities at three markets in the Upper West Region of Ghana, we applied a spatial equilibrium model to identify market strategies that would be useful for the marketing and production decisions of smallholder farmers and, to some extent, the technological dissemination decisions of agricultural staff. Our objective was to use past prices, domestic transportation costs, and shipment quantities to determine current and future trends in the food crop supply and demand and analyze crop marketing strategies.

2.1 Overview of Government Policies on Food Crop Marketing

The agricultural sector in Ghana has experienced many policy interventions. Past agricultural policies have ranged from the socialist model of the 1960s to the liberalized market of the 1980s and 1990s. Many of these policies have consistently kept the country's agricultural output low despite attempts to use agricultural wealth as a springboard for the nation's overall economic development. For instance, the government's policy in the 1960s resulted in a drop in food crop prices, leaving farmers with fewer incentives to produce. At the same time, farmers had to deal with increasingly expensive inputs such as fertilizer because of overvaluation of the Ghana cedi (Assuming-Brempong, 2003). The combined effect was a reduction in the food self-sufficiency rate in the country and increased food imports.

Subsequent efforts were centered on granting subsidies to farmers for essential inputs (e.g., fertilizer and agro-chemicals) and administration of price controls for key agricultural products. According to Aryeetey *et al.* (2000), the Ghana Food Distribution Corporation (GFDC) was set up to trade alongside private traders specifically to provide market outlets for farmers in remote areas. However, these interventions adversely affected the agricultural product market and created problems in the availability and timeliness of agricultural inputs. In 2001, Akiyama *et al.* noted that the interventions amounted to an unsustainable fiscal burden, contributed to a real decline in producer prices as producers often bore the cost of such programs, and failed to produce a significant increase in per capita food production. As a result, agricultural production and productivity in the country declined further. In response to these problems, the Economic Recovery Program/Structural Adjustment Program (ERP/SAP) was initiated. For the agricultural sector, its major focus was the deregulation of both the input and output markets. In general, the policy target was liberalization of the agricultural markets with respect to both individual and aggregate commodity output. As a result, production of crops such as rice and maize that enjoyed guaranteed prices was curtailed, leading to a flood of imported products that freely competed with domestically produced food crops in local markets. Agricultural input subsidies were also removed, and the sector was privatized to ensure efficiency. However, as observed by Assuming-Brempong (1994), this reform resulted in high costs of inputs, which adversely affected agricultural productivity. Understandably, most of the small-scale farmers (who normally have limited income levels) in the country could not afford the inputs for their production activities. In the view of Dorward *et al.* (2005), the outcomes of both the market liberalization and structural adjustment policies that were subsequently introduced were equally mixed.

2.2 Characteristics of Rural Food Crop Markets

In the view of Lyon (2003), the first impression of southern Ghanaian urban markets is usually one of chaos and confusion: huge numbers of traders, a majority of whom are women, sell relatively small quantities of similar produce in cramped and crowded places. Northern Ghanaian markets are the same. In 1997, Fafchamps, who identified similar systems across Africa, referred to such markets as 'informal' markets, because they do not conform to western images of what markets should be like. Poor rural areas are generally characterized by thin markets for agricultural inputs, outputs, and finance. Doward *et al.* (2005) observed that the agricultural business environment in Sub-Saharan Africa is characterized by weak information (regarding prices, new technologies, and other potential market players), high risks (associated with production and prices, but also in terms of access to inputs and markets and contract enforcement), and high transaction costs. High transaction costs for farm produce in rural markets are generally associated with a high cost of assembling produce. A formalized produce marketing system is also lacking. For instance, the average weight of what is known as a 'maxi-bag' of maize differs from location to location (90–109 kg) Also, grain grading is usually by sight and highly subjective. This increases the risk of cheating with regard to weight and quality and makes physical sampling imperative.

2.3 Challenges of Smallholder Farmers and Traders

In 2005, Doward *et al.* catalogued a number of challenges confronting small farmers. These include long production and sales cycles; community-wide seasonality in labor use, cash flow, food availability, prices, and risks; and technical progress and land pressure increasing farmers' needs for small-scale, transaction cost-intensive input purchases, which in turn require seasonal finance and risk mitigation systems that are a particular challenge in subsistence crop production. Moreover, technical choices involving discontinuous switches between technologies and crops cause prices to cross thresholds and simultaneously affect the supply and demand of services and commodities for many farmers. In addition, land tenure arrangements limit farmers' incentives for land improvement and their ability to borrow, expand their farms, or exit agriculture with a lump sum. Coulter and Onumah (2002) observed that rural producers also lack access to price information from local or regional markets, and they are often unable to process complex price-sensitive information when it is available. Besley (1994) also noted that insurance markets virtually did not exist in rural areas, leaving smallholders facing substantial yield and price variability with little or no access to risk management instruments. Coulter *et al.* (2002) reported that rural traders are undercapitalized and have very limited capacity to absorb the surplus output on the market during harvest and post-harvest period, leading to a glut, which depresses farm gate prices, erodes the purchasing power of poor households, and exposes them to food insecurity during the lean season. Rural transactors are often poorly informed. Buyers have limited information about inventories held by rural producers, and formal contract enforcement mechanisms are also weak (Fafchamps, 1996). Hence, rural trade thrives where trust has been developed on the basis of repeated transactions and informal relationships, creating a significant barrier to entry into large-scale food trading by farmers and limiting participation of smallholders in the evolving modern marketing system or in the sub-regional commodity trade.

2.4 Spatial Equilibrium Approach

First developed by Enke (1951) and later by Samuelson (1952) and then reformulated by Takayama and Judge (1964a, 1964b), spatial equilibrium models have been applied to investigate both competitive and monopolistic market situations. Both linear and quadratic programming models have been successfully used to determine dependencies between supply, demand, and prices among spatially separated markets. These models have also been instrumental in providing solutions in cases of interdependencies between markets and multiple commodities in spatial pricing and allocation, and interdependencies with commodities other than the set being considered (Takayama *et al.,* 1964a). Producers are mostly interested in obtaining higher incomes from the sale of their farm products. To achieve this, informed market decision making based on the market situation in each market is crucial. Studies employing these models therefore, equip producers with sufficient knowledge for maximum income determination and shipment scheduling among spatially separated markets. Unfortunately, however, spatial equilibrium studies have mostly focused on transactions related to international trade and urban markets, and relatively little consideration has been given to the complex spatial problems of markets in peri-urban and rural areas. Ignoring of marketing problems of smallholder producers can be a disincentive to agricultural productivity, thereby posing a threat to rural and urban household income and food security.

In their reformulation of Samuelson's spatial equilibrium models, Takayama *et al.* (1964b) developed algorithms that could be used to obtain interregional competitive price and flow solutions for both single products and multiple products for n regions, where regional demands and supplies are represented by continuous, well-behaved linear functions. They defined equilibrium conditions as when the difference in prices between any two regions differs by at most the unit cost of transportation. Thus, in regions in equilibrium between which flows take place, $p_i - p_j = t_{ij}$, where the subscript i and j denote regions i and j, respectively, p is price, and t_{ij} is transport cost between the regions i and j. In regions where $p_i - p_j < t_{ij}$, no flows take place, that is, $x_{ij} = 0$; P_i and P_j represent prices in region i and j, and x_{ij} denote the vector of nonnegative prices at the i, j demand and supply points. These price conditions are consistent with those resulting from the competitive behavior and uncoordinated efforts of n suppliers to sell their output at the maximum possible price. Because the difference in price of a product between different market locations can differ at most by the transportation cost, the Takayama and Judge (1964a, 1964b) models can be applied to multiple commodities and n markets spatially located in peri-urban and rural areas. These model analyses can provide information on the maximum income attainable in each market from produce sales and the shipment scheduling necessary to attain it.

3.1 Study Area

The study area is in the Upper West Region, one of the 10 regions into which Ghana is divided. This region occupies a land area of 18,476 km^2 and lies within the Guinea Savanna Ecological Zone. The 2000 Population and Housing Census of Ghana put the region's population at 576,583 (GSS, 2000a). The average population density is 29.8 persons/km^2. Approximately, 83% of this population lives in rural areas. Owing to the per capita GDP of US $170 (GSS, 2000b) and recurring seasonal famine, the region is the poorest in the country. The adult literacy rate stands at 24.4%, compared with the national average of 53.4%. Similarly, youth literacy hovers at about 36%, whereas the national average is 68.7% (GSS, 2003).

The region is divided into nine administrative districts. Wa, Tumu, and Lawra markets are in the Wa Municipality, the Sissala East District, and the Lawra District, respectively. The total land area of Wa Municipality is 3,143 km^2, and that of Sissala East and Lawra Districts is 4,744 km^2 and 1,051 km^2, respectively. The distance from Wa to Tumu is 134 km, whereas Wa and Lawra are 86 km apart and Tumu and Lawra are 115 km apart. The districts are all in the same ecological zone and hence have the same climatic characteristics. The area has a mono-modal annual rainfall pattern lasting from May to September. The average annual rainfall ranges from 900 to 1,200 mm. During the rather protracted 7-month-long drought period (i.e. October-April), extensive bush burning occurs, mostly deliberately set by humans during hunting or honey tapping. This burning exposes the land surface to severe wind and water erosion. The natural vegetation is characterized by shrubs, stunted grasses, and trees. The soils are relatively fertile, with nutrients concentrated in the top 5 cm. Thus, the soils are very fragile and can be easily made infertile.

The 2000 Population and Housing Census of Ghana reported the total population of Wa Municipality to be 42,802. The population of the Sissala East and Lawra Districts was 85,611 and 67,000, respectively, in 2000. Over 80% of the people live in rural areas with farming as their main economic activity. The main staple crops cultivated are *Zea mays, Sorghum bicolor, Echinochloa frumentacea, Oryza sativa, Vigna unguiculata, Arachis hypogaea, Glycine max* and *Dioscorea rotundata.* Other crops such as *Ipomea batatas, Phaseolus vulgaris, Marcotyloma geocarpum* Harms and vegetables are cultivated at smaller scales. Groundnut and cowpea are mostly considered women's crops in the rural communities. Animals kept include donkeys, cattle, sheep, goats, pigs and fowl.

3.2 Data

The data used for the study were obtained from secondary sources. Monthly wholesale and retail prices (2002-2007) were obtained from the Regional Agricultural Development Unit (RADU). The nominal prices were adjusted for inflation (deflation) using the Consumer Price Index (CPI) with a base year of 19xx, obtained from the Ministry of Finance and Economic Planning. The quantities of each crop shipped to different markets were also obtained from RADU. This data set was used to illustrate the demand trends for maize, sorghum, and groundnut in three markets, Wa, Tumu, and Lawra. Data on inputs were obtained from the Agricultural Extension Handbook (Ministry of Food and Agriculture, 2006). This information was used to assess the technical coefficient of production. Also obtained from RADU records were labor input, average yield and production of crops, and average farm sizes. These data, together with the technical coefficient of production, were used to estimate the total cost of production of each crop in the three (3) districts.

Data used in LP model included transportation charges and production volume of crops. Transportation charges comprise produce transport cost, loading and off-loading costs, and return passenger fares. The data for the quadratic programming model (QP) also include transportation charges and production volumes, but the production volume was obtained by multiplying the production volume of an individual farmer by 250 (the number of members in a farmers' group). In each model, the profit coefficient was obtained by deducting transportation charges from the average market price. The estimated transportation charges differed between LP and QP. In the case of LP, the charges included return passenger fare of the farmer shipping his/her produce to a particular market. In contrast, in QP, the estimated transportation charges did not include return passenger fare because only one member of a farmers' group handles produce shipment to the market locations; thus, the passenger fare has a negligible impact on the profit coefficient of the group. Hence, transportation charges for QP include only the produce transport cost plus loading and off-loading charges. The LP and QP parameter values (parameters are defined in the next section) are presented in Tables 1-4.

3.3 The Model

The spatial equilibrium approach used in this study involves three (3) analysis steps. In the first step, the demand functions of maize, sorghum, and groundnut in the three markets were estimated with a log-linear regression model. A total of three (3) demand functions were estimated since each crop had a separate function. Monthly prices and shipment quantities as well as trend and dummy variables were used for this estimation. The dummy variables were used to capture missing data on market prices and shipment quantities.

The estimated demand function for each crop is given by Equation (1)

$$logQ = a + b\ logX + \sum_{k=1}^{11} c_k DM_k + d_w DW + d_t DT + eTR$$

Table 1. Estimating Shipment Scheduling of Farmers Group Using the Quadratic Programming Model

Variable	Price (X)	Quantity (Q) (bags)*	Price Elasticity	B	a
Wa M aize	18.1	50,277.92	0	0	18.1
Wa Sorghum	24	62,328.00	−0.5713	−0.00022	37.71
Wa Groundnut	39.1	42,565.46	−0.5707	−0.00052	61.41
Tumu Maize	14.4	146,858.64	0	0	14.4
Tumu Sorghum	20.8	93,843.67	−0.5713	−0.00013	32.68
Tumu Groundnut	34.8	42,323.66	−0.5707	−0.00047	54.66
Lawra Maize	18.3	17,071.00	0	0	18.3
Lawra Sorghum	27	45,891.74	−0.5713	−0.00034	42.43
Lawra Groundnut	35.2	119,100.00	−0.5707	−0.00017	55.29

*Maize: 1 bag=100 kg; Sorghum: 1 bag=109 kg; Groundnut: 1 bag=82 kg.

Table 2. Analysis of Shipment Scheduling of Farmers and Farmers' Group in Wa

Models		Linear Programming Model			Quadratic Programming Model		
Variables		Profit Coefficient (Ghana Cedis)	Transportation Cost (Ghana Cedis)	Production Volume (bags)*	Profit Coefficient (Ghana Cedis)	Transportation Cost (Ghana Cedis)	Production Volume (bags)*
Wa	Maize	18.1	0	9.65	18.1	0	2412.5
	Sorghum	24	0	11.94	24	0	2985
	Groundnut	39.2	0	8.2	39.2	0	2050
Tumu	Maize	6.1	−8.3	16.09	14.4	−2.3	4022.5
	Sorghum	12.5	−8.3	10.29	20.8	−2.3	2572.5
	Groundnut	26.5	−8.3	4.65	34.8	−2.3	1162.5
Lawra	Maize	11.2	−7.1	1.74	18.3	−2.1	435
	Sorghum	19.9	−7.1	4.6	27	−2.1	1150
	Groundnut	28.1	−7.1	11.95	35.2	−2.1	2987.5

*Maize: 1 bag=100 kg; Sorghum: 1 bag=109 kg; Groundnut: 1 bag=82 kg.

Where
Q = Total monthly demand in each market
X = Average monthly price in a given market
DM_X = Monthly dummy variables
DW = Dummy variable for Wa market
DT = Dummy variable for Tumu market
TR = Trend variable

Also, whereas k denotes any of the given markets, w and t denote Wa and Tumu markets respectively. The intercept is represented by a. In addition, c_k, d_w, d_t and e denote the coefficients of monthly, Wa market and Tumu market dummy variables, and trend variables respectively. Equation (1) is a quadratic programming model. However, to estimate the demand function we needed to linearize the model. Therefore, I transformed Equation (1) into a log-log linear model by determining the average values of price (X) and quantity (Q). The elasticity of demand is given by b in the equation. This parameter indicates the responsiveness of the quantity produced to changes in price.

The second step involved estimation of the maximum income a farmer could obtain at each market

Table 3. Analysis of Shipment Scheduling of Farmers and Farmers' Group in Tumu

Models		Linear Programming Model			Quadratic Programming Model		
Variables		Profit Coefficient (Ghana Cedis)	Transportation Cost (Ghana Cedis)	Production Volume (bags)*	Profit Coefficient (Ghana Cedis)	Transportation Cost (Ghana Cedis)	Production Volume (bags)*
Wa	Maize	9.8	−8.3	9.65	15.8	−2.3	2412.5
	Sorghum	15.7	−8.3	11.94	21.7	−2.3	2985
	Groundnut	30.9	−8.3	8.2	36.9	−2.3	2050
Tumu	Maize	14.4	0	16.09	14.4	0	4022.5
	Sorghum	20.8	0	10.29	20.8	0	2572.5
	Groundnut	34.8	0	4.65	34.8	0	1162.5
Lawra	Maize	13.1	−5.2	1.74	16.1	−2.2	435
	Sorghum	21.8	−5.2	4.6	24.8	−2.2	1150
	Groundnut	30	−5.2	11.95	33	−2.2	2987.5

*Maize: 1 bag = 100 kg; Sorghum: 1 bag = 109 kg; Groundnut: 1 bag = 82 kg.

Table 4. Analysis of Shipment Scheduling of Farmers and Farmers' Group in Lawra

Models		Linear Programming Model			Quadratic Programming Model		
Variables		Profit Coefficient (Ghana Cedis)	Transportation Cost (Ghana Cedis)	Production Volume (bags)*	Profit Coefficient (Ghana Cedis)	Transportation Cost (Ghana Cedis)	Production Volume (bags)*
Wa	Maize	11	−7.1	9.65	16	−2.1	2412.5
	Sorghum	16.9	−7.1	11.94	21.9	−2.1	2985
	Groundnut	32.1	−7.1	8.2	37.1	−2.1	2050
Tumu	Maize	9.2	−5.2	16.09	12.2	−2.2	4022.5
	Sorghum	15.6	−5.2	10.29	18.6	−2.2	2572.5
	Groundnut	29.6	−5.2	4.65	32.6	−2.2	1162.5
Lawra	Maize	18.3	0	1.74	18.3	0	435
	Sorghum	27	0	4.6	27	0	1150
	Groundnut	35.2	0	11.95	35.2	0	2987.5

*Maize: 1 bag = 100 kg; Sorghum: 1 bag = 109 kg; Groundnut: 1 bag = 82 kg.

by suitable shipment scheduling. In this step, farmers are considered price takers. The estimation involved the use of a linear programming model, given by Equation (2):

$$\text{Max: } \sum_{k=1}^{3}(P_k^W - c^w)q_k^W + \sum_{k=1}^{3}(P_k^T - c^T)q_k^T + \sum_{k=1}^{3}(P_k^L - c^L)q_k^L$$

subject to P_k^W, P_k^T, P_k^L *= constant*

$q_k^0 \geq q_k^W + q_k^T + q_k^L$

$0.25q_k^0 \geq q_k^W \geq 0$

$0.25q_k^0 \geq q_k^T \geq 0$

$0.25q_k^0 \geq q_k^L \geq 0$

k = 1 (*Maize*), 2 (*Sorghum*), 3 (*Groundnut*)

W: *Wa market*, *T*: *Tumu market*, *L*: *Lawra market*

P: Market price, c: Transportation cost, q: Shipping volume

$$\text{Max:}\quad \begin{pmatrix} P_1^W-c^W & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & P_2^W-c^W & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & P_3^W-c^W & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & P_1^T-c^T & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & P_2^T-c^T & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & P_3^T-c^T & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & P_1^L-c^L & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & P_2^L-c^L & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & P_3^L-c^L \end{pmatrix} \begin{pmatrix} q_1^W \\ q_2^W \\ q_3^W \\ q_1^T \\ q_2^T \\ q_3^T \\ q_1^L \\ q_2^L \\ q_3^L \end{pmatrix}$$

$$\text{s.t.}\quad \begin{pmatrix} q_1^0 \\ q_2^0 \\ q_3^0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix} \geq \begin{pmatrix} 1 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 1 \\ -0.75 & 0 & 0 & 0.25 & 0 & 0 & 0.25 & 0 & 0 \\ 0 & -0.75 & 0 & 0 & 0.25 & 0 & 0 & 0.25 & 0 \\ 0 & 0 & -0.75 & 0 & 0 & 0.25 & 0 & 0 & 0.25 \\ 0.25 & 0 & 0 & -0.75 & 0 & 0 & 0.25 & 0 & 0 \\ 0 & 0.25 & 0 & 0 & -0.75 & 0 & 0 & 0.25 & 0 \\ 0 & 0 & 0.25 & 0 & 0 & -0.75 & 0 & 0 & 0.25 \\ 0.25 & 0 & 0 & 0.25 & 0 & 0 & -0.75 & 0 & 0 \\ 0 & 0.25 & 0 & 0 & 0.25 & 0 & 0 & -0.75 & 0 \\ 0 & 0 & 0.25 & 0 & 0 & 0.25 & 0 & 0 & -0.75 \end{pmatrix} \begin{pmatrix} q_1^W \\ q_2^W \\ q_3^W \\ q_1^T \\ q_2^T \\ q_3^T \\ q_1^L \\ q_2^L \\ q_3^L \end{pmatrix}$$

In this model, the maximum income of a farmer for any shipment quantity can be calculated by the objective function shown in equation (2). However, in applying this model, two factors must be taken into account. First, farmers in the Upper West Region of Ghana are by nature risk averse and will not put all their eggs in one basket (or sell entire produce in one market). Hence, I assumed that a farmer would ship not less than 25% of total production to each market. Second, a farmer within a particular market location does not have to pay transportation charges when shipping produce to that same market. The means of transport for both individual farmers and farmers' groups in the Upper West Region is truck.

The final analysis step was estimation of shipment scheduling and maximum income for a farmers' group. The group is considered a price maker because of its large number of members and produce volume. A quadratic programming model is used in this estimation, given by Equation (3). The assumptions made in LP regarding shipping destinations and quantities also apply in QP model.

$$\text{Max: } \sum_{k=1}^{3}(P_k^W-c^w)q_k^W + \sum_{k=1}^{3}(P_k^T-c^T)q_k^T + \sum_{k=1}^{3}(P_k^L-c^L)q_k^L$$

subject to $P_k^W = a_k^W + b_k^W\ (\overline{q_k^W} + q_k^W)$

$P_k^T = a_k^T + b_k^W(\overline{q_k^T} + q_k^T)$

$P_k^L = a_k^L - b_k^L(\overline{q_k^L} + q_k^L)$

$q_k^0 \geq q_k^W + q_k^T + q_k^L$

$0.25q_k^0 \geq q_k^W \geq 0$

$0.25q_k^0 \geq q_k^T \geq 0$

$0.25q_k^0 \geq q_k^L \geq 0$

k = 1 (*Maize*), 2 (*Sorghum*), 3 (*Groundnut*)

W: *Wa market, T*: *Tumu market, L*: *Lawra market*

P: Market price, c: Transportation cost, q: Shipping volume

$$\text{Max:}\quad \begin{pmatrix} q_1^W \\ q_2^W \\ q_3^W \\ q_1^T \\ q_2^T \\ q_3^T \\ q_1^L \\ q_2^L \\ q_3^L \end{pmatrix}^t \begin{pmatrix} b_1^W & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & b_2^W & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & b_3^W & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & b_1^T & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & b_2^T & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & b_3^T & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & b_1^L & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & b_2^L & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & b_3^L \end{pmatrix} \begin{pmatrix} q_1^W \\ q_2^W \\ q_3^W \\ q_1^T \\ q_2^T \\ q_3^T \\ q_1^L \\ q_2^L \\ q_3^L \end{pmatrix} + \begin{pmatrix} Z_1^W & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & Z_2^W & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & Z_3^W & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & Z_1^T & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & Z_2^T & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & Z_3^T & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & Z_1^L & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & Z_2^L & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & Z_3^L \end{pmatrix} \begin{pmatrix} q_1^W \\ q_2^W \\ q_3^W \\ q_1^T \\ q_2^T \\ q_3^T \\ q_1^L \\ q_2^L \\ q_3^L \end{pmatrix}$$

Where $Z_K^M = a_k^M + b_k^M\,(\overline{q_k^M}) - c^M \qquad k=1\sim3,\ M=W,\ T,\ L$

$$\text{s.t.}\quad \begin{pmatrix} q_1^0 \\ q_2^0 \\ q_3^0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix} \geq \begin{pmatrix} 1 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 1 \\ -0.75 & 0 & 0 & 0.25 & 0 & 0 & 0.25 & 0 & 0 \\ 0 & -0.75 & 0 & 0 & 0.25 & 0 & 0 & 0.25 & 0 \\ 0 & 0 & -0.75 & 0 & 0 & 0.25 & 0 & 0 & 0.25 \\ 0.25 & 0 & 0 & -0.75 & 0 & 0 & 0.25 & 0 & 0 \\ 0 & 0.25 & 0 & 0 & -0.75 & 0 & 0 & 0.25 & 0 \\ 0 & 0 & 0.25 & 0 & 0 & -0.75 & 0 & 0 & 0.25 \\ 0.25 & 0 & 0 & 0.25 & 0 & 0 & -0.75 & 0 & 0 \\ 0 & 0.25 & 0 & 0 & 0.25 & 0 & 0 & -0.75 & 0 \\ 0 & 0 & 0.25 & 0 & 0 & 0.25 & 0 & 0 & -0.75 \end{pmatrix} \begin{pmatrix} q_1^W \\ q_2^W \\ q_3^W \\ q_1^T \\ q_2^T \\ q_3^T \\ q_1^L \\ q_2^L \\ q_3^L \end{pmatrix}$$

4. Model Results

4.1 Demand Function of Crops

Table 5 shows the estimated demand function results for maize, sorghum, and groundnut. The results indicate a negative and insignificant elasticity of demand (b=−0.00742) for maize. This means that price remains relatively constant as the quantity demanded changes. The results for sorghum also revealed a negative elasticity of demand (b=−0.57131), which was significant at the 10% level, implying that price does not remain constant. A change in the quantity demanded results in a change in price. In the case of groundnut, the results showed a negative elasticity of demand (b=−0.5707), and the results were significant at the 15% level, implying that the price is not constant in relation to demand. Instead, the price is determined by the total quantity of the crop in the market at a given time.

4.2 Shipment Scheduling and Maximum Income of Individual Farmers Estimated with the Linear Programming Model

Individual farmers are considered price takers. Given the constraint that farmers ship not less than 25% of their total produce to each market because of low risk tolerance, a farmer in Wa can obtain a maximum income of 641.713 Ghana cedis, indicated by the profit coefficient (Table 6). However, effective shipment planning is required. The farmer should sell 50% of the production volume of each crop (maize, sorghum, and groundnuts) in the Wa market and 25% each in the Tumu and Lawra markets. For a maximum income of 565.727 Ghana cedis, a farmer in Tumu should sell 50% of the production volume of maize and groundnuts in the Tumu market and 25% each in the Wa and Lawra markets. However, the farmer should sell 50% of the production volume of sorghum in the Lawra market and 25% each in the Tumu and Wa markets (Table 7). For a maximum income of 518.832 Ghana cedis, a farmer in Lawra should sell 50% of the total production volume of each crop in the Lawra market and 25% each in Wa and Tumu markets (Table 8).

4.3 Shipment Scheduling and Maximum Income of a Farmers' Group Estimated with the Quadratic Programming Model

Each farmer's group consists of 250 members and is considered a price maker. The maximum income of a farmer's group in Wa is 181,466.7 Ghana cedis (Table 6). This implies that the income of each member of the group is up to 725.867 Ghana cedis. The group, however, should sell 50% of the total production of maize and groundnut in the Wa market, and 25% each should be shipped to the Lawra and Tumu markets. In the case of sorghum, 50% should be sold in the Lawra market and 25% each in the Wa and Tumu markets. The maximum income of a farmers' group in Tumu is 163064.3 Ghana cedis (Table 7). Hence, each member is entitled to 652.257 Ghana cedis. The group should sell 50% of maize in the Lawra market and 25% each in Wa and Tumu markets. In the case of sorghum, 50% must be sold in the Lawra market while shipping 25% each to the Tumu and Wa markets. For groundnut, 50% should to be shipped to the Wa market and 25% each to the Lawra and Tumu markets. The results for a Lawra-based farmers' group are presented in

Table 5. Estimation of Demand Functions for Maize, Sorghum and Groundnut

Crops	(Intercept)	Elasticity of Demand (b)	Adjusted R^2
Maize	11.00593	$-0.00742^{N.S.}$ (-0.039)	0.4533
Sorghum	12.52736	-0.57131^{**} (-1.912)	0.4306
Groundnut	8.9585	-0.57070^{*} (-1.542)	0.6993

t statistic is in parentheses; * Significant at the 10 % level.
** Significant at the 15% level; N.S. Not significant.

Table 6. Estimations of Shipment Scheduling and Maximum Income of Farmers and Farmers' Group in Wa

Models		Linear Programming Model	Quadratic Programming Model
Maximum Income (Ghana Cedis)		641.713	181466.7
Wa	Maize	4.83	1206.25
	Sorghum	5.97	746.25
	Groundnut	4.1	1025
Tumu	Maize	2.41	603.12
	Sorghum	2.99	746.25
	Groundnut	2.05	512.5
Lawra	Maize	2.41	603.13
	Sorghum	2.99	1492.5
	Groundnut	2.05	512.5

Table 7. Estimations of Shipment Scheduling and Maximum Income of Farmers and Farmers' Group in Tumu

		Linear Programming Model	Quadratic Programming Model
Maximum Income (Ghana Cedis)		565.727	163064.3
Wa	Maize	4.02	1005.63
	Sorghum	2.57	643.13
	Groundnut	1.16	581.25
Tumu	Maize	8.05	1005.63
	Sorghum	2.57	643.13
	Groundnut	2.33	290.63
Lawra	Maize	4.02	2011.25
	Sorghum	1.15	1286.25
	Groundnut	1.16	290.63

Table 8. Estimations of Shipment Scheduling and Maximum Income of Farmers and Farmers' Group in Lawra

		Linear Programming Model	Quadratic Programming Model
Maximum Income (Ghana Cedis)		518.832	140125.6
Wa	Maize	0.44	108.75
	Sorghum	1.15	287.5
	Groundnut	2.99	1493.75
Tumu	Maize	0.44	108.75
	Sorghum	1.15	287.5
	Groundnut	2.99	746.88
Lawra	Maize	0.87	217.5
	Sorghum	2.3	575
	Groundnut	5.99	746.88

Table 8. The maximum income is 140125.6 Ghana cedis, so each member of the farmers' group should earn 560.502 Ghana cedis. The shipment programming results showed that the group is required to sell 50% of maize and sorghum in the Lawra market and 25% each in the Wa and Tumu markets. In the case of groundnuts, 50% should be sold in Wa and 25% each in the Tumu and Lawra markets.

4.4 Discussion

Analysis of monthly market prices of the crops in the Upper West Region of Ghana indicated a fluctuating price trend. The insignificant and negative elasticity of demand in the case of maize is attributable to its ready availability in the area (Table 5); despite its high cost of production, more than 90% of farmers in the region cultivate maize annually. The region shares borders with the Brong Ahafo and Upper East Regions of Ghana and with Burkina Faso, all of which have relatively higher maize production levels. Consumers can therefore easily import maize from these areas, thereby driving down the higher prices that would result from a lower supply. Hence, price remains relatively constant.

The price of sorghum is highly determined by quantity. It is a staple crop and also used for small-scale industrial purposes (i.e., brewing local beer called 'pito'). The crop is also a raw material for commercial brewing companies. Demand for the crop is therefore very large. However, annual production fails to meet consumer demand. Unlike maize, the neighboring regions do not have a comparative advantage in sorghum production because of poor soils and the prevalence of *Striga,* a parasitic weed on sorghum. As a result, the price of sorghum is very sensitive to its supply. Similar to sorghum, the price of groundnuts is also determined by the quantity available in the market. Groundnut is a major cash crop in the area and has numerous food and industrial uses. Compared to maize and sorghum, groundnut has the highest market value. The business environment of groundnut is characterized by large numbers of small- to medium-scale producers and buyers and sellers from within and outside the region.

The results of the linear and quadratic programming models (outlined in Tables 6–8) indicated that individual farmers (considered as price takers) make less income than their counterparts involved in farmers' group (i.e., price makers). In the Wa area, whereas individual farmers have access to a maximum income of approximately 642 Ghana cedis, a member of farmers' group can earn 726 Ghana cedis from the sale of crops. In Tumu, a member of a farmers' organization can earn 652 Ghana cedis, but an individual farmer earns much less. The situation is similar for farmers in Lawra. The total cost to a farmer of taking his produce to market affects his profit coefficient. Farmers in the region produce small volumes, making it expensive to sell in towns. We found that the transport cost for an individual farmer is approximately twice the per capita cost for members of a farmers' group, because the individual farmer has to pay return passenger fare and expenses for food in addition to the produce shipment cost. With proper shipment scheduling, farmers in Wa can obtain a higher maximum income than their counterparts in Tumu and Lawra, and farmers in Tumu also have a higher maximum income that those in Lawra. Members of farmers' groups based in Wa can earn 726 Ghana cedis, whereas their counterparts in Tumu and Lawra can earn only 652 and 560 Ghana cedis, respectively (Tables 6–8).

5. Conclusion and Recommendations

5.1 Conclusion

In this study, a spatial equilibrium approach was applied to determine appropriate marketing strategies for maize, sorghum, and groundnut producers in the Upper West Region of Ghana. Three major markets were considered in the assessment. First, price trends and demand functions of the crops were estimated. Then, using linear and quadratic programming models, respectively, shipment programming and the maximum income of a price maker (i.e., a farmers' group) and price taker (i.e., individual farmers) were estimated and compared. The results showed that prices of maize and groundnut are generally higher in Wa market, but the price of sorghum is higher in Lawra market. Among the three crops, however, maize has the lowest market value in all markets. Moreover, farmers in the Wa area have a higher maximum income than those in Tumu or Lawra. The results also indicated that farmers can obtain higher maximum incomes as price makers than as price takers. We found that transportation charges are a huge marketing constraint on farmers. The effect of this constraint is larger on the profit coefficient of a price taker.

The estimated results of LP and QP models are, of course, normative. However, in addition to LP and QP, other stochastic programming models can give normative results or solutions. Such results are determined by the existing market situation, farmers' behaviors, and government interventions. These three (3) inputs are, however, interrelated. For instance, produce market price, production volumes, and transportation charges have enormous impact on the marketing decisions and strategies of farmers, and the values of these parameters are not constant, but are subject to high annual variations. For example, transportation charges are mostly influenced by fuel prices, which in turn are affected by highly volatile global crude oil prices. Similarly, government intervention in the form of price controls or guarantees erode the price variations between markets, thereby affecting shipment decisions of farmers. When the parameter values are very unstable, the LP and QP results for maximum income determination and shipment programming may not hold for a long period of time. Thus, it is prudent to carry out a separate analysis for each probable socioeconomic situation in each area to anticipate unforeseen contingencies.

5.2 Recommendations

Access to high farm income by farmers remains a critical motivation for achieving high agricultural production and productivity. Revenue from the sale of farm produce is a major source of income to smallholder farmers. This comparative assessment showed that farmers can obtain higher incomes from produce sales as price makers than as price takers because transportation charges constitute a huge barrier to achieving higher incomes from crop sales. In this situation, a key marketing strategy is for farmers to form marketing groups/cooperatives. Farmers also need to have access to crop market price information and should be able to make appropriate shipment decisions at any point in time. The role of the agricultural extension staff in the region is therefore threefold: facilitate the establishment of farmer marketing groups, provide market price information, and assist farmers in carrying out shipment programming.

Acknowledgements

My profound gratitude goes to my research supervisor, Professor Shusuke Matsushita. His unstinting guidance, numerous reviews and constructive criticisms made the completion of this article possible. I also express sincere thanks to the distinguished members of my research committee, Professor Suminori Takunaga and Professor Hisato Shuto. Their comments and contributions to my research have been invaluable. Thanks also go the Regional Director, Mr. Emmanuel Eledi, and staff of the Upper West Regional Directorate (UWR-RADU) of the Ministry of Food and Agriculture (MOFA), Ghana. I appreciate your efforts in providing me the necessary data and information required for my research. I would also like to acknowledge Japan International Co-operation Agency (JICA) for sponsoring my studies at the University of Tsukuba.

References

Akiyama, T., Baffes, J., Larson, D. and Varangis, P. Commodity Market Reforms: Lessons of Two Decades, Regional and Sectoral Studies, The World Bank, Washington, DC (2001). http://econ.worldbank.org/external / default / main? pagePK = 64165259 & piPK = 64165421&theSitePK = 469372&menuPK = 64216926 & entityID = 000094946_01040505302967 (Accessed March 2008).

Aryeetey E., J. Harrigan and M. Nissankee (Eds.) 2000. Economic Reforms in Ghana. Woeli Publishing Services. Accra, Ghana.

Assuming-Brempong, S., 2003. Economic and Agricultural Policy Reforms and their Effects on the Role of Agriculture in Ghana. FAO Roles of Agricultural Project (ROA)International Conference. ftp://ftp.fao.org/es/ESA / Roa / pdf 1 -policy / policy-Ghana. pdf (Accessed February 2008).

Assuming-Brempong, S., 1994. Exchange Rate Liberalization and Input Subsidy Removal: In issues in Africa rural development2. S. A. Berth (Ed.) Winrock International Institute for Rural Development. USA.

Besley, T., 1994 How do market failures justify interventions in rural financial markets. World Bank Research Observer 9 (1994), pp. 27-47. http://dissertations.ub.rug. nl / FILES / faculties / eco / 2005 / h. t. mehrteab / referenc.pdf (Accessed March 2008).

Coulter, J. and Onumah, G., 2002.The role of warehouse receipt systems in enhanced commodity marketing and rural livelihoods in Africa. http://www.sciencedirect.com / science / article / B6VCB-4777857-3 / 2 / 219cf7e 9237cedf00ea8737d57065ba2 (Accessed May 2008).

Doward, A., Kydd, J. and Poulton C., 2005. Beyond Liberalization: "Developmental Coordination" Policies for African Smallholder Agriculture. Institute for Development Studies. IDS Bulletin volume 36 No 2 http://www.ids.ac.uk/index.cfm (Accessed April 2008).

Enke, S., 1951. Equilibrium Among Spatially Separated Markets: Solution by Electric Analogue.1 Econometrica, vol. 19, pp. 40–47.

Fafchamps, M., 1997. Markets in Sub-Sahara Africa. World Development 25.5 733–4.

Fafchamps, M., 1996. The enforcement of commercial contracts in Ghana. World Development 24.3 pp. 427–448. http: //www.sciencedirect.com/science?_ob=Article URL&_udi=B6VC6-3VVVNJK-2&_user=128923&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000010078&_version=1&_urlVersion=0&_userid=128923&md5=923df136765ade7b0b54b8dad2b56508 (Accessed March 2008).

Getnet, K., 2007. From market liberalization to market development: The need for market institutions in Ethiopia, Economic Systems (2007). doi: 101016/J.ECOSYS.2007.10.003

Ghana Statistical Service., 2003. Core Welfare Indicators

Questionnaire (CWIQ) Survey. www.ndpc.gov.gh/ pdf/NationalRegional.pdf (Accessed September 2008).

Ghana Statistical Service, 2000a. Population Housing and Census.

Ghana Statistical Service, 2000b. Poverty Trends in the 1990s.

IFAD, 2007. Improving marketing strategies in Central and West Africa. http://www.ruralpovertyportal.org/ English / learn / agriculture / cassava. htm (Accessed May 2008).

Lyon F., 2003. Trader Associations and Urban Food Systems in Ghana: Institutionalist Approaches to Understanding Urban Collective Action. International Journal of Urban and Regional Research. Volume 27.1. http://econpapers.respec.org/article/blaijurrs/ (Accessed February 2008).

Ministry of Food and Agriculture, 2006. Agriculture Extension Handbook. Ghanaian-German Agriculture Development Project (GTZ).

Ministry of Food and Agriculture, 2006. Facts and Figures. Statistics, Research and Information Directorate.

Samuelson, P.A., 1952. Spatial Price Equilibrium and Linear Programming. The American Economic Review, vol. 42.

Takayama, T. and Judge, G.G., 1964a. Equilibrium Among Spatially Separated Markets: A Reformulation. Econometrica, 32 (4): 510–524.

Takayama, T. and Judge, G.G., 1964b. Spatially Equilibrium Separated and Quadratic: Programming. Journal of Farm Economics, 46: 67–93.